

A hyperspectral imaging method in accordance with one embodiment comprises the following steps: (1) the camera is installed on the platform; (2) if insufficient technical information about the camera is available (e.g., from the manufacturer), a calibration process is used to determine how optical transmittance of the color filter varies with incidence angle at various wavelengths (this step is performed only once); (3) the user or the computer directs the camera to take multiple images of the same target, orienting the camera to put the target off-center by a different angle for each image; (4) the computer inputs the image data from the camera; (5) software running on the computer processes the images to resolve fine-grained spectral bins at selected locations in the scene; and (6) the computer outputs a data record of fine-grained spectral information for the selected locations.

One aspect of the disclosure provides a method for measuring a spectrum of at least one point in a scene using a camera which comprises a three-color filter array and an array of photosensors, the method comprising: calibrating the camera by measuring transmittance values of the filters of the three-color filter array for each one of a multiplicity of synthetic spectral bands at a multiplicity of angles of incidence; moving the camera to a first location comprising a position and an orientation so that a scene is within a field of view of the camera; capturing a first image of the scene while the camera is at said first location; moving the camera to a second location comprising approximately the same position and a different orientation so that the scene is within the field of view of the camera; capturing a second image of the scene while the camera is at said second location; transferring the first and second images from the camera to a computer system; and computing the spectrum of a point in the scene based on image data of said first and second images acquired by respective photosensors receiving light from said point and measured transmittance values of respective filters of the three-color filter array disposed in front of the respective sensors receiving light from said point, said computing being performed by the computer system.

Another aspect of the disclosure provides a method for measuring a spectrum of at least one point in a scene, comprising: characterizing a camera which comprises a multi-color filter array and an array of photosensors; locating the camera at a position with a first orientation so that a scene is within a field of view of the

camera; capturing a first image of the scene while the camera is at said position with said first orientation; locating the camera at said position with a second orientation so that the scene is within the field of view of the camera; capturing a second image of the scene while the camera is at said position with said second orientation; transferring the first and second images from the camera to a computer system; and computing the spectrum of a point in the scene based on at least said first and second images, said computing being performed by the computer system, wherein characterizing the camera comprises measuring a transmittance as a function of wavelength and of incidence angle.

Another aspect of the disclosure provides a method for measuring a spectrum of at least one point in a scene, comprising: characterizing a camera which comprises a multi-color filter array and an array of photosensors; locating the camera at a position with a first orientation so that a scene is within a field of view of the camera; capturing a first image of the scene while the camera is at said position with said first orientation, wherein the first image comprises a first pixel corresponding to a point in the scene and comprising a first RGB triplet of intensity values; locating the camera at said position with a second orientation so that the scene is within the field of view of the camera; capturing a second image of the scene while the camera is at said position with said second orientation, wherein the first image comprises a first pixel corresponding to the point in the scene and comprising a second RGB triplet of intensity values; capturing a second image of the scene while the camera is at said position with said second orientation; transferring the first and second images from the camera to a computer system; computing a first set of transmittance values for a multiplicity of synthetic spectral bands at a first angle of incidence of a light ray from the point in the scene to a first photosensor corresponding to the first pixel; computing a second set of transmittance values for the multiplicity of synthetic spectral bands at a second angle of incidence of a light ray from the point in the scene to a second photosensor corresponding to the second pixel; forming a matrix of transmittance values that includes the first and second sets of transmittance values; and computing the spectrum of the point in the scene based on at least said first and second images by respectively multiplying the intensity values of the first and second RGB triplets by elements of a matrix which is an inverse of the matrix of transmittance values, wherein the computing steps are performed by the computer

system.

Another aspect of the disclosure provides a method for measuring a spectrum of at least one point in a scene, comprising: characterizing a camera which comprises a multi-color filter array and an array of photosensors; locating the camera at a position with a first orientation so that a scene is within a field of view of the camera; capturing a first image of the scene while the camera is at said position with said first orientation; locating the camera at said position with a second orientation so that the scene is within the field of view of the camera; capturing a second image of the scene while the camera is at said position with said second orientation; transferring the first and second images from the camera to a computer system; and computing the spectrum of a point in the scene based on at least said first and second images, said computing being performed by the computer system, wherein the computed spectrum comprises intensity values for each of a multiplicity of synthetic spectral bands.

One aspect of the subject matter disclosed in detail below is a method of measuring the spectrum of at least one point in a scene, comprising: characterizing a camera which comprises a multi-color filter array and an array of photosensors; locating the camera at a position with a first orientation so that a scene is within a field of view of the camera; capturing a first image of the scene while the camera is at the position with the first orientation; locating the camera at the position with a second orientation so that the scene is within the field of view of the camera; capturing a second image of the scene while the camera is at the position with the second orientation; transferring the first and second images from the camera to a computer; and computing the spectrum of a point in the scene based on at least the first and second images, the computing being performed by the computer system. In accordance with some embodiments, characterizing the camera comprises measuring a transmittance as a function of wavelength and of incidence angle, and the computed spectrum comprises intensity values for each of a multiplicity of synthetic spectral bands. In accordance with those same embodiments, the first and second images respectively comprise first and second pixels corresponding to the point in the scene, which pixels each comprise first and second RGB triplets of intensity values.

CLAIMS

1. A method for measuring a spectrum of at least one point in a scene using a camera which comprises a three-color filter array and an array of photosensors, the method comprising:

calibrating the camera by measuring transmittance values of the filters of the three-color filter array for each one of a multiplicity of synthetic spectral bands at a multiplicity of angles of incidence;

moving the camera to a first location comprising a position and an orientation so that a scene is within a field of view of the camera;

capturing a first image of the scene while the camera is at said first location;

moving the camera to a second location comprising approximately the same position and a different orientation so that the scene is within the field of view of the camera;

capturing a second image of the scene while the camera is at said second location;

transferring the first and second images from the camera to a computer system; and

computing the spectrum of a point in the scene based on image data of said first and second images acquired by respective photosensors receiving light from said point and measured transmittance values of respective filters of the three-color filter array disposed in front of the respective sensors receiving light from said point, said computing being performed by the computer system.

2. The method as recited in claim 1, wherein said calibrating step comprises measuring a transmittance of a filter of the three-color filter array as a function of wavelength and of incidence angle.

3. The method as recited in claim 1, wherein the point in the scene is imaged in the first image at a first distance from the optical axis of the camera, and the point in the

scene is imaged in the second image at a second distance from the optical axis of the camera, the second distance being different than the first distance.

4. The method as recited in claim 1, wherein the first image comprises a first pixel corresponding to the point in the scene, and the second image comprises a second pixel corresponding to the point in the scene, the first and second pixels respectively comprising first and second RGB triplets of intensity values.

5. The method as recited in claim 4, further comprising:

computing a first set of transmittance values of a first filter of the three-color filter array for a multiplicity of synthetic spectral bands at a first angle of incidence of a light ray from the point in the scene to a first photosensor corresponding to the first pixel;

computing a second set of transmittance values of a second filter of the three-color filter array for the multiplicity of synthetic spectral bands at a second angle of incidence of a light ray from the point in the scene to a second photosensor corresponding to the second pixel; and

forming a matrix of transmittance values that includes the first and second sets of transmittance values,

wherein computing the spectrum comprises respectively multiplying the intensity values of the first and second RGB triplets by elements of a matrix which is an inverse of the matrix of transmittance values.

6. The method as recited in claim 1, wherein the camera is attached to a vehicle or a robot.

7. The method as recited in claim 6, wherein moving the camera comprises maneuvering the vehicle or robot.

8. The method as recited in claim 6, wherein the vehicle is one of the following group: an aircraft, a spacecraft, a ground vehicle, a boat, or a submersible.

9. The method as recited in claim 1, wherein the computed spectrum comprises intensity values for each of a multiplicity of synthetic spectral bands.

10. The method as recited in claim 9, wherein at least one synthetic spectral band is chosen after capture of the first image.

11. A method for measuring a spectrum of at least one point in a scene, comprising:
characterizing a camera which comprises a multi-color filter array and an array of photosensors;

locating the camera at a position with a first orientation so that a scene is within a field of view of the camera;

capturing a first image of the scene while the camera is at said position with said first orientation;

locating the camera at said position with a second orientation so that the scene is within the field of view of the camera;

capturing a second image of the scene while the camera is at said position with said second orientation;

transferring the first and second images from the camera to a computer system;
and

computing the spectrum of a point in the scene based on at least said first and second images, said computing being performed by the computer system,

wherein characterizing the camera comprises measuring a transmittance as a function of wavelength and of incidence angle.

12. The method as recited in claim 11, wherein the point in the scene is imaged in the first image at a first distance from the optical axis of the camera, and the point in the scene is imaged in the second image at a second distance from the optical axis of the camera, the second distance being different than the first distance.

13. The method as recited in claim 11, wherein the first image comprises a first pixel

corresponding to the point in the scene, and the second image comprises a second pixel corresponding to the point in the scene, the first and second pixels respectively comprising first and second RGB triplets of intensity values.

14. The method as recited in claim 11, wherein the camera is attached to a vehicle or a robot.

15. A method for measuring a spectrum of at least one point in a scene, comprising:
characterizing a camera which comprises a multi-color filter array and an array of photosensors;

locating the camera at a position with a first orientation so that a scene is within a field of view of the camera;

capturing a first image of the scene while the camera is at said position with said first orientation, wherein the first image comprises a first pixel corresponding to a point in the scene and comprising a first RGB triplet of intensity values;

locating the camera at said position with a second orientation so that the scene is within the field of view of the camera;

capturing a second image of the scene while the camera is at said position with said second orientation, wherein the first image comprises a first pixel corresponding to the point in the scene and comprising a second RGB triplet of intensity values;

capturing a second image of the scene while the camera is at said position with said second orientation;

transferring the first and second images from the camera to a computer system;

computing a first set of transmittance values for a multiplicity of synthetic spectral bands at a first angle of incidence of a light ray from the point in the scene to a first photosensor corresponding to the first pixel;

computing a second set of transmittance values for the multiplicity of synthetic spectral bands at a second angle of incidence of a light ray from the point in the scene to a second photosensor corresponding to the second pixel;

forming a matrix of transmittance values that includes the first and second sets of transmittance values; and

computing the spectrum of the point in the scene based on at least said first and second images by respectively multiplying the intensity values of the first and second RGB triplets by elements of a matrix which is an inverse of the matrix of transmittance values,

wherein the computing steps are performed by the computer system.

16. The method as recited in claim 15, wherein the camera is attached to a vehicle or a robot.

17. The method as recited in claim 16 wherein locating the camera comprises maneuvering the vehicle or robot.

18. The method as recited in claim 16, wherein the vehicle is one of the following group: an aircraft, a spacecraft, a ground vehicle, a boat, or a submersible.

19. A method for measuring a spectrum of at least one point in a scene, comprising:
characterizing a camera which comprises a multi-color filter array and an array of photosensors;

locating the camera at a position with a first orientation so that a scene is within a field of view of the camera;

capturing a first image of the scene while the camera is at said position with said first orientation;

locating the camera at said position with a second orientation so that the scene is within the field of view of the camera;

capturing a second image of the scene while the camera is at said position with said second orientation;

transferring the first and second images from the camera to a computer system;
and

computing the spectrum of a point in the scene based on at least said first and second images, said computing being performed by the computer system, wherein the

computed spectrum comprises intensity values for each of a multiplicity of synthetic spectral bands.

20. The method as recited in claim 19, wherein at least one synthetic spectral band is chosen after capture of the first image.